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(19)



Europäisches Patentamt

European Patent Office

Office européen des brevets



(11)

EP 1 170 915 A1

(12)

EUROPEAN PATENT APPLICATION

published in accordance with Art. 158(3) EPC

(43) Date of publication:

09.01.2002 Bulletin 2002/02

(51) Int Cl.7: H04L 27/20

(86) International application number:

PCT/JP00/02124

(21) Application number: 00913062.6

(22) Date of filing: 31.03.2000

(87) International publication number:

WO 00/59172 (05.10.2000 Gazette 2000/40)

(84) Designated Contracting States:
DE FR

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(30) Priority: 31.03.1999 JP 9171799

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Patent- und Rechtsanwälte Arabellastrasse 4
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(54) SIGNAL MODULATION CIRCUIT AND METHOD FOR SIGNAL MODULATION

(57) A phase signal is modulated in quadrature modulation by a quadrature modulator 5, and the frequency of the modulated phase signal is converted into carrier frequency by a frequency converter 7. An amplitude signal extracted from the modulating signal is delayed by a delay circuit 23, and an output gain signal designating the output average power gain is supplied

to the output signal of the delay circuit 23. Synchronization of the frequency modulated phase signal and the amplitude signal delayed and added to the output gain signal allows to obtain an RF signal with little out of band noise even if the modulating signal contains amplitude variation. Therefore, the RF signal with little out of band noise is output even if the modulating signal contains amplitude variation.

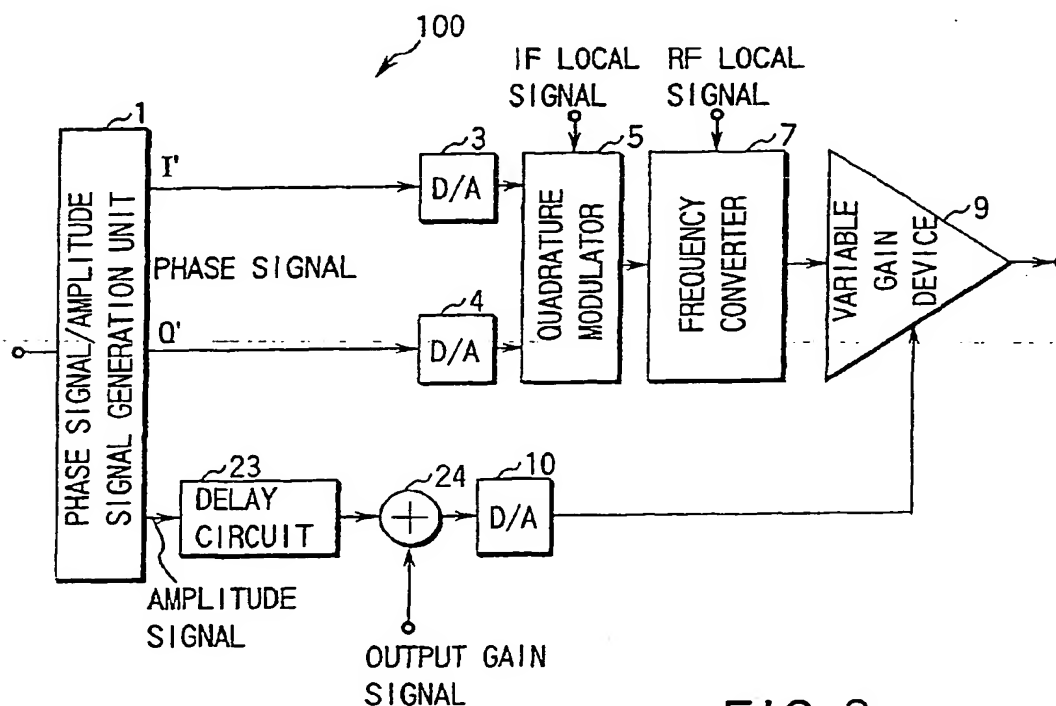


FIG. 3

Description

Technical Field

[0001] The present invention relates to a signal modulation system and, especially, a signal modulation system for modifying a signal based on a phase signal and an amplitude signal extracted from a modulating signal and, for example the signal modulation system for modifying a signal in the transmission unit of a cellular phone.

Background Art

[0002] Some of conventional signal modulation circuits and signal modulation methods are described in (1) "An Up-Conversion Loop Transmitter IC for Digital Mobile Telephones" (Siemens Microelectronics/1998 IEEE ISSCC SP 23.1), and (2) "A 2.7V 900MHz/1.9GHz DUAL-BAND TRANSCEIVER IC FOR DIGITAL WIRELESS COMMUNICATION" (Rockwell International/1998 IEEE CICC).

[0003] The modulation method described in the reference documents (1) and (2) may not apply to the modulation whose amplitude signal varies, since the method adopts a circuit for signal processing of sole phase signal only by phase synchronization loop.

[0004] In order to cope with a modulation form where the amplitude signal changes, for instance, $\pi/4$ shift QPSK ($\pi/4$ shift Quadrature Phase Shift Keying), it is necessary to adopt a construction as shown in FIG. 2 of the reference document (3) "Transmitter architectures [GSM hand set]" (1998 IEEE CDDCH). However, in this construction, modulated wave contains wave B as shown in FIG. 1 as out of band noise, since frequency of a modulating signal is converted without processing by the phase synchronization loop. It is necessary to use many voluminous and expensive filters to remove such out of band noise. There is a problem of increasing disadvantageously volume and cost of signal modulation system.

Disclosure of Invention

[0005] The present invention has an object to provide a signal modulation system for obtaining a RF (radio frequency) signal with little out of band noise, even for modulating signal whose amplitude signal changes.

[0006] According to the present invention, there is provided:

a modulation circuit for obtaining a modulated signal, by modulating a carrier signal using a modulating signal, comprising:

extracting means for extracting a phase signal and an amplitude signal from the modulating signal;
 analog converting means for converting the phase signal output from the extracting means into an analog signal and for outputting the analog signal;
 first frequency-signal generating means for generating a first oscillation frequency signal;
 quadrature modulating means for modulating, in use of quadrature modulation, the analog signal output from the converting means to an IF signal, based on the first oscillation frequency signal, and for outputting the IF signal;
 second frequency-signal generating means for generating a second oscillation frequency signal,
 frequency converting means for converting the frequency of the IF signal output from the quadrature modulating means and converting the IF signal into a RF signal, based on the second oscillation frequency signal, and for outputting the RF signal;
 delaying means for delaying the amplitude signal output from the extracting means for a time, and for outputting the amplitude signal; and
 outputting means for varying the amplitude of the RF signal and amplifying the varied RF signal in accordance with the delayed amplitude signal output from the delaying means, and for outputting the amplified RF signal.

[0007] Further, according to the present invention, there is provided:

a modulation circuit for obtaining a modulated signal, by modulating a carrier signal using a modulating signal, comprising:

extracting means for extracting a phase signal and an amplitude signal from the modulating signal;
 quadrature modulating means for digitally modulating, in use of quadrature modulation, the phase signal output from the extracting means to an IF signal, and for outputting the IF signal;

analog converting means for converting the IF signal output from the quadrature modulating means into an analog IF signal, and for outputting the analog signal;
 frequency converting means for converting the frequency of the analog IF signal output from the analog converting means and converting the analog IF signal into a RF signal, and for outputting the RF signal;
 5 delaying means for delaying the amplitude signal output from the extracting means for a time, and for outputting the amplitude signal; and
 outputting means for varying the amplitude of the RF signal and amplifying the varied RF signal output from the frequency converting means in accordance with the delayed amplitude signal output from the delaying means, and for outputting the amplified RF signal.

10 [0008] Moreover, according to the present invention, there is provided:

— — — — — a method for obtaining a modulated signal, by modulating a carrier signal using a modulating signal, comprising: — — — — —

15 an extracting step for extracting a phase signal and an amplitude signal from the modulating signal;
 an analog converting step for converting the phase signal output from the extracting step into an analog signal and for outputting the analog signal;
 a first frequency-signal generating step for generating a first oscillation frequency signal;
 a quadrature modulating step for modulating, in use of quadrature modulation, the analog signal output from
 20 the analog converting means to an IF signal, based on the first frequency signal, and for outputting the IF signal;
 a second frequency-signal generating step for generating a second oscillation frequency signal;
 a frequency converting step for converting the frequency of the IF signal output in the quadrature modulating step, for converting the IF signal into a RF signal, based on the second oscillation frequency signal, and for outputting the RF signal;
 25 a delaying step for delaying the amplitude signal output in the extracting step for a time, and for outputting the amplitude signal; and
 an amplifying step for varying the amplitude of the RF signal output in the frequency converting step and amplifying the varied RF signal in accordance with the delayed amplitude signal output in the delaying step, and outputting the amplified RF signal.

30 [0009] Furthermore, according to the present invention, there is provided:

a modulation circuit for obtaining a modulated signal, by modulating a carrier signal using a modulating signal, comprising:

35 an extracting step for extracting a phase signal and an amplitude signal from the modulating signal;
 a quadrature modulating step for digitally modulating, in use of quadrature modulation, the phase signal output in the extracting means to an IF signal and for outputting the IF signal;
 an analog converting step for converting the IF signal output in the quadrature modulating means into an analog IF signal and for outputting the analog IF signal;
 40 a frequency converting step for converting the frequency of the analog IF signal output in the analog converting means and converting the analog IF signal into a RF signal and for outputting the RF signal;
 a delaying step for delaying the amplitude signal output in the extracting means for a time and for outputting the amplitude signal; and
 45 an amplifying step for varying the amplitude of the RF signal output in the frequency converting means and amplifying the varied RF signal in accordance with the delayed amplitude signal output in the delaying means, and outputting the amplified RF signal.

Brief Description of Drawings

50 [0010]

FIG. 1 is a spectral distribution diagram showing schematically a modulated wave containing information which should be transmitted (wave A) and a carrier having wave including out of band noise (wave B);
 55 FIG. 2 is a block diagram showing the outline of a cellular phone including a signal modulation circuit according to an embodiment of the present invention;
 FIG. 3 is a block diagram showing the signal modulation circuit shown in FIG. 2;
 FIG. 4 is a block diagram showing the signal modulation circuit shown in FIG. 3 and illustrating the circuit of quad-

rature converter and frequency converter more in detail;

FIGS. 5A and 5B are waveform diagrams of a phase signal input to the signal modulation circuit shown in FIG. 3 and FIG. 4, respectively, an example waveform diagram (A) of amplitude variation to the time of a phase signal I and an example waveform diagram (B) of amplitude variation to the time of a phase signal Q for a base band analog modulating signal modulated by GMSK modulation method;

FIGS. 6A and 6B are waveform diagrams of a phase signal input to the signal modulation circuit shown in FIG. 3 and FIG. 4, respectively, an example diagram (A) of amplitude variation to the time of a signal combining a phase signal I and a phase signal Q for a base band analog modulating signal modulated by GMSK modulation method and an example diagram (B) of phase variation to the time of a signal combining a phase signal I and a phase signal Q;

FIG. 7 is a waveform diagram of a phase signal input to the signal modulation circuit shown in FIG. 3 and FIG. 4, and is a phase signal trajectory diagram showing a trajectory indicating history of a phase signal I and Q on an IQ plane, for phase signals I and Q for a base band analog modulating signal modulated by GMSK modulation method;

FIGS. 8A and 8B are waveform diagrams of a phase signal input to the signal modulation circuit shown in FIG. 3 and FIG. 4, respectively, an example waveform diagram (A) of amplitude variation to the time of a phase signal I and an example waveform diagram (B) of amplitude variation to the time of a phase signal Q for a base band analog modulating signal modulated by $\pi/4$ shift QPSK modulation method;

FIGS. 9A and 9B are waveform diagrams of a phase signal input to the signal modulation circuit shown in FIG. 3 and FIG. 4, respectively, an example waveform diagram (A) of amplitude variation to the time of a signal combining a phase signal I and a phase signal Q and an example waveform diagram (B) of phase variation to the time of a signal combining a phase signal I and a phase signal Q for a base band analog modulating signal modulated by $\pi/4$ shift QPSK modulation method;

FIG. 10 is a waveform diagram of a phase signal input to the signal modulation circuit shown in FIG. 3 and FIG. 4, and is a phase signal trajectory diagram showing a trajectory indicating history of phase signals I and Q on an IQ plane, for phase signals I and Q for a base band analog modulating signal modulated by $\pi/4$ shift QPSK modulation method;

FIG. 11 is a block diagram showing the outline of a signal modulation circuit according to another embodiment of the present invention;

FIG. 12 is a block diagram showing the signal modulation circuit shown in FIG. 11 and illustrating the circuit of quadrature converter and frequency converter more in detail;

FIG. 13 is a block diagram showing the outline of a signal modulation circuit according to further another embodiment of the present invention;

FIG. 14 is a block diagram showing the outline of a signal modulation circuit according to still another embodiment of the present invention;

FIG. 15 is a graph of output power for control voltage in the linearity correction unit shown in FIG. 14, showing an actual response curve (solid line) illustrating the output power response to the control voltage, and an ideal response straight line (dotted line) illustrating the output power response to the control voltage; and

FIG. 16 is a block diagram showing the outline of a signal modulation circuit according to further still another embodiment of the present invention.

Best Mode for Carrying Out of the Invention

[0011] Now, an embodiment of signal modulation circuit of the present invention will be described referring to attached drawings.

[0012] A concrete example of a signal modulation circuit and a signal modulation method according to an embodiment of the present invention will be described referring to FIG. 2 to FIG. 10. FIG. 2 is a block diagram showing the construction of essential parts of a cellular phone including a signal modulation circuit 100 according to this embodiment.

[0013] The cellular phone shown in FIG. 2 comprises an antenna 101, an antenna switch 102, a receiving circuit (RX) 103, a synthesizer circuit (SYN) 104, an analog/digital (A/D) converter 105, a demodulation unit 106, a channel codec 107, a speech codec 108, a digital/analog (D/A) converter 109, a receiving voice amplifier 110, a receiver 111, a microphone 112, a transmitting voice amplifier 113, an A/D converter 114, a control circuit 117, an LCD display 118, a key unit 119, an amplifier 120, a speaker 121, an oscillation circuit 122, a CPU 123, a ROM 124, a RAM 125, a battery 126 and a stabilizing power supply circuit 127.

[0014] There, synthesizer circuit 104, demodulation unit 106, channel codec 107, speech codec 108, control circuit 117, ROM 124 and RAM 125 are connected to the CPU 123 via a control bus 128.

[0015] A radio frequency signal transmitted from a radio base station via a radio communication channel is received by the antenna 101, subjected to electric wave/electric signal conversion, and the converted signal is input into the receiving circuit 103 via the antenna switch 102.

[0016] First, the radio frequency signal is amplified in the receiving circuit 103. Then, the radio frequency signal is converted into IF (intermediate frequency) signal through mixing-down using local signal given by the synthesizer circuit 104. Further, this IF signal is amplified by the receiving circuit 103 and, then, demodulated in use of quadrature de-

5 [0017] Here, the synthesizer circuit 104 generates a local signal of the frequency designated by the CPU 123 in accordance with frequency of the radio channel, and the local signal is supplied to the receiving circuit 103 and the signal modulation circuit 100.

[0018] An IF signal demodulated in quadrature modulation by the receiving circuit 103, is digitized by the A/D converter 105 and is supplied to the demodulation unit 106.

10 [0019] A signal output from the receiving circuit 103 is demodulated by the demodulation unit 106 and, DC offset elimination, phase synchronization, frame synchronization, waveform equalization, or the like are implemented, and a digital communication signal is reproduced.

[0020] The digital communication signal output from the demodulation unit 106 is subjected to deinterleave and error correction decoding in the channel codec 107. This allows to pick up a digital communication signal addressed to self-
15 phone among digital communication signals containing a plurality of channels which are included in the digital communication signal output from the demodulation unit 106.

[0021] A digital communication signal output from the channel codec 107 is decoded by the speech codec 108 to reproduce a receiving sound signal.

20 [0022] Then this receiving sound signal is converted to an analog signal by the D/A converter 109, amplified by the receiving voice amplifier 110, and supplied to the receiver 111. Thereby, the receiver 111 is driven to convert a receiving sound signal into a sound output signal, and the receiving sound is supplied to a user.

[0023] On the other hand, the sound voiced by the user is converted into an electric signal, namely a transmitting voice signal by the microphone 112. This transmitting voice signal is amplified by the transmitting voice amplifier 113 and then digitized by the A/D converter 114.

25 [0024] The digitized transmitting voice signal is coded by the speech codec 108 to make a digital origination call signal.

[0025] The digital origination call signal obtained by the speech codec 108 is subjected to error correction coding by the channel codec and interleave.

30 [0026] Further, the digital communication signal is input into the signal modulation circuit 100 of the present invention, modulated and amplified as predetermined, and then supplied to the antenna 101 through the antenna switch 102. Thus, the radio frequency signal is transmitted as a radio wave from the antenna 101.

[0027] Under the control of the CPU 123, the control circuit 117 controls drive of the LCD display 118 and the speaker 121, and processes an output signal of the key unit 119.

[0028] Driven by the control circuit 117, the LCD display 118 displays any image.

35 [0029] The key unit 119 accepts inputs designated by the user concerning telephone number, origination call, termination of a call, character input or function setting.

[0030] The amplifier 120 is supplied with a signal output from the control circuit 117 for driving the speaker 121 to ring receiving sound. The amplifier 120 amplifies this signal and this signal is supplied to the speaker 121.

40 [0031] The speaker 121 generates a signal given by the control circuit 117 through the amplifier 120 as a sound output, and thereby rings the receiving sound to inform a receiving signal to the user.

[0032] The oscillation circuit 122 supplies the control circuit 117 with a preset clock signal.

[0033] The CPU 123 functions based on the operating program stored in the ROM 124. The CPU 123 controls globally each of components in this cellular phone so as to function as a cellular phone.

45 [0034] The ROM 124 is composed of flash ROM or EEPROM. This ROM 124 is used for storing, in addition to the operating program of the CPU 123, melody information, animation information, still image information, specified numbers, information for adjusting radio apparatus or various information to be stored permanently.

[0035] The RAM 125 is used for storing setting states of the cellular phone, for example, telephone numbers, digitized recording signals, user input character information, user input melody information or various information to be stored for a relatively short period. As supported by a backup battery not shown, this RAM 125 can safely stored information
50 for a relatively long period.

[0036] The battery 126 is a secondary battery and generates electric power to be supplied to each of components of this cellular phone.

[0037] The stabilizing supply circuit 127 stabilizes the power output from the battery 126 for supplying to each of components.

55 [0038] A concrete example of the signal modulation circuit 100 included in the aforementioned cellular phone will be described referring to FIG. 2 and FIG. 4. In this example, a RF signal can be obtained with little out of band noise even for a modulating signal containing amplitude variation, by means of a variable gain device 9 for varying gain based on the amplitude signal extracted from the modulating signal.

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[0039] The modulation circuit shown in FIG. 3 comprises a phase signal/amplitude signal generation unit 1, D/A converters 3,4,10, a quadrature modulator 5, a frequency converter 7, a variable gain device 9, a delay circuit 23 and an adder 24.

[0040] In the aforementioned construction, a phase signal component and amplitude signal component are extracted from the modulating signal by this phase signal/amplitude signal generation unit 1. The phase signal component is decomposed into $I'(t)$, $Q'(t)$ quadrature components.

[0041] Here, suppose a wave amplitude signal of a base band modulation is $A(t)$, a phase signal of the base band modulation wave is $\theta(t)$, an in-phase component $I(t)$ and a quadrature component $Q(t)$ of the base band modulation wave are expressed as follows respectively:

$$I(t) = A(t) \cos \theta(t);$$

$$Q(t) = A(t) \sin \theta(t).$$

In this modulation wave, when a carrier having frequency f_c is modulated, the modulated wave $s(t)$ can be expressed by :

$$\begin{aligned} s(t) &= I(t) \cos \theta(2\pi f_c t) \\ &\quad - Q(t) \sin \theta(2\pi f_c t) \\ &= A(t) \cos \theta(t) \cos \theta(2\pi f_c t) \\ &\quad - A(t) \sin \theta(t) \sin \theta(2\pi f_c t) \\ &= A(t) \cos \theta(2\pi f_c t + \theta(t)). \end{aligned}$$

[0042] Then, $I'(t)$, $Q'(t)$ can be expressed as $\cos \theta(t)$ and $\sin \theta(t)$ respectively having an amplitude component 1. Hereinafter, $I'(t)$, $Q'(t)$ will be described simply as I' and Q' .

[0043] At a position indicated on the IQ plane where the phase signal corresponds to a transmission information, the magnitude of a vector having the I' and Q' quadrature components is always constant. When the modulation form is, for instance, QPSK, the magnitude of a vector having I' and Q' quadrature components is always constant at four signal points on the IQ plane. In the other modulation forms, $\pi/4$ shift QPSK, the magnitude of a vector having I' and Q' quadrature components is always constant at eight signal points on the IQ plane. In other words, at eight signal points on the IQ plane, phase signals I' and Q' are in the following relationship:

$$I'^2 + Q'^2 = \text{constant}.$$

[0044] As for these phase signal and amplitude signal, as a concrete example, values stored previously in the memory may be read out corresponding to a modulating signal given by the control of CPU and output as a phase signal and amplitude signal.

[0045] A base band digital modulating signal is supplied from the phase signal/amplitude signal generation unit 1 to the D/A converters 3, 4 and is converted into an analog signal. In the quadrature modulator 5, an IF local signal is converted in a method of quadrature modulation with use of output signals from the D/A converters 3, 4, and the IF local signal converted in a method of quadrature modulation is output from the quadrature modulator 5.

[0046] In the frequency converter 7, frequency of the IF signal is converted into carrier frequency using a RF local signal input from an input terminal of the RF local signal. In general, the IF signal frequency f_{IF} , the RF local signal frequency f_{local} and the carrier frequency $f_{carrier}$ have a following relationship:

$$f_{carrier} = f_{local} - f_{IF},$$

or

$$f_{\text{carrier}} = f_{\text{local}} + f_{\text{IF}}$$

[0047] Here, carrier wave can be set to frequency corresponding to respective channels by making frequency f_{local} of the RF local signal variable.

[0048] The delay circuit 23 adjusts transfer time difference between a system of a D/A converter 34, a quadrature modulator 5 and a frequency converter 7 on a transmission line of the phase signal, and a system of a delay circuit 23, an adder 24 and a D/A converter 10 on a transmission line of the amplitude signal. After the modulating signal passes the delay circuit 23, the amplitude signal of the modulating signal is synthesized, by the adder 24, with an output gain signal designating the output electric power average value to be transmitted. The output signal of the adder 24 is converted into an analog signal by the D/A converter 10 and becomes a gain control signal of the variable gain device 9.

[0049] The variable gain device 9 amplifies power of the phased modulated RF signal output from the frequency converter 7 with a gain indicated by gain control signal output from the D/A converter 10. A modulated wave signal can be obtained with the output from the variable gain device 9 by synthesizing a phase component and an amplitude signal of the modulation wave.

[0050] In this embodiment, a phase-synchronizing modulation loop 70 is applied as a frequency converter 7 of the modulation circuit, as shown in FIG. 4. FIG. 3 shows a block diagram of the signal modulation circuit when the phase-synchronizing modulation loop 70 is applied as frequency a converter 7.

[0051] The circuit shown in FIG. 4 can generate PSK (Phase Shift Keying) signal such as GMSK modulation.

[0052] In FIG. 4, this modulation circuit comprises a phase signal/amplitude signal generation unit 1 that is supplied a base band digital modulating signal, digital/analog (D/A) converters 3, 4, an quadrature modulator 5, and an IF synthesizer 6. Here, the quadrature modulator 5 comprises multipliers 51, 52, phase shifters 53, 54 and an adder 55. Moreover, a phase-synchronizing modulation loop 70, an RF synthesizer 8 and a PA (power amplifier) 9 are included. Here, the phase-synchronizing modulation loop 70 comprises a low-pass filter 71, an M counting-down circuit 72, a down converter mixer 73, a low-pass filter 74, an N counting-down circuit 75, a PFD (phase frequency detector) 76, a loop filter 77 and a VCO (voltage controlled oscillator) 78. Moreover, an D/A converter 10 is connected to the PA 9.

[0053] Now, the operation of the aforementioned signal modulation circuit will be described. Phase signals I' and Q' are input to the D/A converters 3, 4 from the phase signal/amplitude signal generation unit 1 to which base band digital modulating signal is given. In the D/A converters 3, 4, a base band digital modulating signal input from the phase signal/amplitude signal generation unit 1 is converted into an analog signal. Output signals from the D/A converters 3, 4 are frequency converted into modulated IF signal in quadrature modulation, through multiplication by the output signal of the IF synthesizer 6 in the quadrature modulator 5. In case of multiplying the output signal of the IF synthesizer 6 by the output signal from the D/A converters 3, 4, the difference between the phase of the output signal of the IF synthesizer 6 to multiply with the output signal from the D/A converter 3, and the phase of the output signal of the IF synthesizer 6 to multiply with the output signal from the D/A converter 4 is set to 90 degrees ($\pi/2[\text{rad}]$). Then, by multiplying with the output signal from the multipliers 51, 52, modulated IF signal in use of quadrature modulation is output as output signal of the quadrature modulator 5. In other words, the phase shifter 53 delays phase of the output signal from the IF synthesizer 6 by 45 degrees ($\pi/4[\text{rad}]$), while the phase shifter 54 advances phase of the output signal from the IF synthesizer 6 by 45 degrees ($\pi/4[\text{rad}]$). Each of phase shifted signals is supplied to the multipliers 51, 52 as a local signal. These phase phase devices 53, 54 make the phase difference between the local signal input to the multiplier 51 and the local signal input to the multiplier 52 is set 90 degrees ($\pi/2[\text{rad}]$). By adding the output signal from the multipliers 51, 52 in the adder 55, modulated IF signal in use of quadrature modulation is output as an output signal of the quadrature modulator 5.

[0054] The phase-synchronizing modulation loop 70 frequency converts the IF signal output from the quadrature modulator 5 into a desired carrier frequency, using the RF synthesizer 8 as a local signal. In the low-pass filter 71, harmonic components of the IF signal which is an output signal of the quadrature modulator 5 is eliminated, and the output signal is input into the M counting-down circuit 72. The down converter mixer 73 converts the frequency of the modulated RF signal, by multiplying modulated RF signal of the VCO 78, mentioned below, and a local signal of the RF synthesizer 8. The low-pass filter 74 eliminates image signals or spurious signals included in the output signal of the down converter mixer 73. The N counting-down circuit 75 divides frequency of an output signal of the low-pass filter 74 by N. The PFD 76 compares frequency or phase of an output signal of the M counting-down circuit 72 and the N counting-down circuit 75, and outputs a signal corresponding to two input signals to be compared. The loop filter 77 smoothes an output signal of the PFD 76 and, also, determines characteristics of this phase-synchronizing modulation loop 70. The VCO is a voltage control oscillator to change the frequency to be oscillated corresponding to an input control voltage.

[0055] Signal polarity or other characteristics output from the PFD 76 can be set variously. Here, for example, if output signal frequency of the M counting-down circuit 72 is higher than output signal frequency of the counting-down

circuit 75, or output signal phase of the M counting-down circuit 72 is in advance of output phase of the counting-down circuit 75, it is set to output positive pulse current and to enlarge the pulse width in proportion to their value difference. The loop filter 77 smoothes pulse current which is a PFD 76 output signal, and outputs a voltage corresponding to the pulse width. The VCO 78 control characteristics are set to advance the phase and raise the oscillation frequency as much as the input voltage value is higher. In other words, if the output signal phase of the M counting-down circuit 72 is in advance of the output phase of the N counting-down circuit 75, the phase of the voltage control oscillator 78 is controlled to advance. Now, if the RF synthesizer 8 frequency is set to lower side frequency of the carrier, the down converted signal phase advances as much as the voltage control oscillator 78 phase advances. Consequently, the output signal phase of the N counting-down circuit 75 that has divided the frequency of the down converted signal. On the other hand, if the output signal phase of the N counting-down circuit 75 is in advance of the output phase of the M counting-down circuit 72, this phase-synchronizing modulation loop 70 delays the oscillation phase of the voltage control oscillator 78. Namely, this phase-synchronizing modulation loop 70 follows the phase of IF signal from the quadrature modulator 5, and the phase of the voltage control oscillator 78 changes. Eventually, the oscillation frequency of the voltage control oscillator 78 is locked, and this oscillation frequency corresponds to the carrier frequency f_{carrier} generated by the signal modulation circuit. The value of this carrier frequency is as follows:

$$f_{\text{carrier}} = (N/M) f_{\text{IF}} + f_{\text{local}}$$

[0056] Here, f_{local} is oscillation frequency of the RF synthesizer 8, f_{IF} is IF oscillation frequency of the synthesizer 6, M is division numbers of the counting-down circuit 72 and N is division numbers of the counting-down circuit 75.

[0057] Carrier phase of each channel can be modulated by changing frequency f_{carrier} of the RF synthesizer 8 in correspondence with the channel.

[0058] The power amplifier 9 amplifies an output signal from the phase-synchronizing modulation loop 70 to a predetermined output power. An output power of the power amplifier 9 is controlled by a control unit not shown.

[0059] As mentioned above, since in the signal modulation circuit shown in FIGS. 3, 4 the loop filter is constructed in accordance with frequency in the loop filter, a frequency error or undesirable spurious emission diminish, allowing to obtain a good modulation spectral characteristics, if a loop gain is sufficient.

[0060] The signal modulation circuit of the present invention may modulate a modulating signal to a carrier with little band noise, even if the modulating signal has unstable and variable amplitude. In other words, even when the modulation form is changed from GMSK (Gaussian-filtered Minimum Shift Keying) to $\pi/4$ shift QPSK, a signal from a signal processing unit not shown controls delay time of the delay circuit 23, and therefore the signal can be modulated into a carrier with little band noise.

[0061] Now, signal characteristics of GMSK which is a modulation form with stable and invariable amplitude, and signal characteristics of $\pi/4$ shift QPSK which is a modulation form with unstable and variable amplitude are described referring to FIG. 5 to FIG. 10.

[0062] FIG. 5 shows an example of waveform according to time of phase signals I and Q in base band digital modulating signals of GMSK. The time axis which is a horizontal axis shown in FIG. 5, is normalized with a symbol rate. FIG. 6 shows an amplitude component and phase component which are divided from the waveform shown in FIG. 5. FIG. 7 shows, on the IQ plane, the phase signal components shown in FIG. 5.

[0063] As it is obvious from FIG. 6, an amplitude signal of GMSK signal is always constant. In FIG. 7, it is also understandable that the amplitude is constant, as an orbit of points of positioning a phase signal on the IQ plane are always on a constant circle.

[0064] On the other hand, FIG. 8 shows an example of waveform according to time of phase signals I and Q in base band digital modulating signals of $\pi/4$ shift QPSK. As shown in FIG. 11, the horizontal axis of FIG. 8 is normalized with a symbol rate. FIG. 9 shows an amplitude component and phase component which are divided from the waveform shown in FIG. 8. FIG. 10 shows, on the IQ plane, the phase signal shown in FIG. 8.

[0065] As it is obvious from FIG. 9, the amplitude signal of the $\pi/4$ shift QPSK signal contains an amplitude variation of about -8[dB] to +2[dB]. Also in FIG. 10, it is understandable that the amplitude varies with time, as an orbit of points of positioning a phase signal on the IQ plane does not remain on a constant circle.

[0066] Using the signal modulation circuit and signal modulation method of this embodiment, it becomes possible to provide a cellular phone allowing to obtain a RF signal with little out of band noise even if the modulating signal contains an amplitude variation, by means of a variable gain device 9 changing a gain based on amplitude signal which is extracted from the modulating signal.

[0067] A concrete example of signal modulation circuit 100 contained in the cellular phone of another embodiment of the present invention will be described referring to FIG. 11 and FIG. 12. This embodiment corresponds to a signal modulation circuit provided further with a power amplification unit mounted behind the variable gain device 9. The modulation circuit shown in FIG. 11 is provided further with a power amplifier 9-2 and a D/A converter 10 connected

to the power amplifier 9-2, in addition to the construction shown in FIG. 3.

[0068] In the signal modulation circuit shown in FIG. 3, a power gain signal and amplification signal designating output average power were synthesized in the adder 24 placed in the base band digital unit. In this embodiment, the output average power is controlled separately from the control according to delay the amplitude signal. Namely, an amplification gain is changed by inputting only an output gain signal corresponding to output average power into the power amplifier 9-2 through the D/A converter 10. The amplitude signal is converted, after transfer time is adjusted by the delay circuit 23, into an analog value by a newly mounted D/A converter 25, and then inputs as a gain control signal of the variable gain device 9. The amplitude signal of modulating signal in the variable gain device 9 is synthesizing with a signal modulated in phase, the signal being output from the frequency converter 7, and then a modulated wave is output from the variable gain device 9. Moreover, the output signal of the variable gain device 9 is power amplified in the power amplifier 9-2 in corresponding with the output average power value, and in final a transmission signal is output. This series of operations assures a high precision modulation.

[0069] It is also possible to construct the aforementioned modulation circuit by replacing the order of the variable gain device 9 and the power amplifier 9-2 controlled respectively by the D/A converters 10, 25. Namely, it may so construct to control the gain of the power amplifier 9-2 by the output signal of the D/A converter 25, and the gain of the variable gain device 9 by the output signal of the D/A converter 10.

[0070] To be more detailed, as shown in FIG. 12, an up-converting mixer is used inside a frequency converter 79.

[0071] In FIG. 12, this frequency converter 79 comprises an IF band pass filter 11, a limiting amplifier 11-2, an up-converting mixer 12 and a band pass filter 13. Signal-to-noise ratio of the IF signal input into the up-converting mixer 12 can be improved by further amplifying an amplitude of the IF signal passed through the IF band pass filter 11.

[0072] In other words, since a mixer 12, a variable gain device 9 or the like may be operated in non linearity with respect to an amplitude, transmission of good signal-to-noise ratio can be realized with low power consumption.

[0073] In FIG. 12, the signal modulation circuit comprises a phase signal/amplitude signal generation unit 1, D/A converters 3, 4, a quadrature converter 5, an IF synthesizer 6 and an RF synthesizer 8.

[0074] Out of band undesired signal components of an output signal from the quadrature modulator 5 is eliminated by the band-pass filter 11, multiplied with a local signal output from the RF synthesizer 8 in the up-converting mixer 12, and then frequency of the out of band undesired signal components is converted into that in radio frequency band. As an output signal of the mixer 12 includes an image signal, a spurious signal or out-of-band noise components (wave B shown in FIG. 1), these signal and noise component are eliminated by the band pass filter 13 to obtain a carrier of a genuine wave (wave A shown in FIG. 1) which contains information to be transferred. An output signal of filter 13 is previously filtered by a driver amplifier 14 and then input into the power amplifier 9. A power gain of the power amplifier 9 is controlled by a control unit not shown.

[0075] In the modulation system, as a phase synchronization loop is not formed, noise from respective steps preceding to the power amplifier 9 are added up, and they are and appear in an output signal of the power amplifier 9. In order to prevent noise from leaking out of this system transmission band, normally, a system band pass filter 15 having a steep band selection characteristics is set at an output of the power amplifier 9.

[0076] A concrete example of signal modulation circuit 100 contained in the cellular phone of further another embodiment of the present invention will be described referring to FIG. 13. This embodiment corresponds to a signal modulation circuit provided further with a delay-time setting unit 26 which sets the necessary time corresponding to the transfer path, for setting the delay time precisely by this delay-time setting unit. Here, the delay circuit 23 can change delay time by a delay time signal input from the delay-time setting unit 26. In other word, the delay circuit 23 is inserted into the transfer path to adjust transfer time difference between a phase signal passing through D/A converters 3, 4, quadrature modulator 5 and frequency converter 7 on the transfer path, and an amplitude signal passing through delay circuit 23 and D/A converter 10 on the transfer path. There, quadrature modulator 5 and frequency converter 7 are similar to the quadrature modulator 5, frequency converter 7 or frequency converter 79 shown in FIG. 4 or 12. Moreover, circuit components not otherwise specified are similar to those shown in FIG. 3 or FIG. 4.

[0077] The delay time of each of transfer paths is not always constant, but it may vary according to modulating signal type, modulation index, frequency band, level diagram in each step, ambient temperature or other various factors. As the delay circuit 23 is provided with a function to vary the delay time, in case a roll off rate of the modulating signal of $\pi/4$ shift QPSK, for example, varies or in another case a system communication band has shifted considerably, the delay circuit 23 delay time can be adjusted for the best modulation by a command from the signal processing unit not shown. Consequently, in the delay-time setting unit 26, out of band noise can be reduced precisely, by setting optimal delay time of each moment, based on parameters or variation factors of transfer time difference, such as, at least ambient temperature, modulating signal frequency, supply voltage, or the like.

[0078] A concrete example of the signal modulation circuit 100 contained in the cellular phone of still another embodiment of the present invention will be described referring to FIG. 14. This embodiment corresponds to a signal modulation circuit wherein linearity of an amplitude signal delayed by the delay unit 23 and added with an output gain signal designating the output average power, is compensated by a linearity correction unit.

[0079] The linearity corrector 27 shown in FIG. 14 is the one for correcting the linearity between an input value and an output value based on an expression for defining the output value or a conversion table, according to the input value. The linearity corrector 27 corrects the linearity of output power characteristics in function of control voltage of the variable gain device 9. There, quadrature modulator 5 and frequency converter 7 are similar to the quadrature modulator 5, frequency converter 7 or frequency converter 79 shown in FIG. 1 or FIG. 4. Moreover, circuit components not otherwise specified are similar to those shown in FIG. 3 or FIG. 4.

[0080] Now, an example of output power characteristics in function of control voltage of the variable gain device 9 is shown in FIG. 15. In FIG. 15, the horizontal axis shows the control voltage, and the vertical axis shows the output power. In the example of the output power characteristics in function of the control voltage shown in FIG. 15, the relationship between the control voltage and the output power of the variable gain device 9 is certainly monotonic increase, but its linearity is not good. Therefore, the linearity corrector 27 corrects to obtain linearity of relationship between the amplitude signal of the modulating signal and the output power. In this embodiment, characteristics of output power versus modulated amplitude are corrected as the dotted line shown in FIG. 15. For instance, in order to obtain an output power of 1[W], a digital value showing 0.82[V] is input to the linearity corrector 27, however, a digital value showing 1.07 [V] is output from the linearity corrector 27. Namely, the linearity corrector 27 is provided with a conversion table for outputting an input value in regarding the input value of the horizontal axis shown by the broken line in FIG. 15 as that of the horizontal axis shown by the solid line in FIG. 15.

[0081] Otherwise, a conversion formula to describe the solid line by an approximation formula is given. Suppose output power in the variable gain device 9 is P_o and control voltage V_{cnt} , P_o and V_{cnt} can be related by the expression:

$$P_o = A \times V_{cnt} + B,$$

for the straight line. If the correspondence is made, for instance, by the expression:

$$P_o = C \times (1 - \cos(D \times V_{cnt})),$$

output power modulation amplitude characteristics closer to the straight line, compared to the output power modulation amplitude characteristics before the linear correction, can be obtained by such linear correction.

[0082] Even if the linearity of the variable gain device 9 gain control characteristics is not good, the modulation accuracy of an output wave of a final modulation wave synthesized by the variable gain device 9 can be maintained, as the linearity corrector 27 can compensate according to that linearity.

[0083] A concrete example of signal modulation circuit 100 contained in the cellular phone of further still another embodiment of the present invention will be described referring to FIG. 16. This embodiment corresponds to a signal modulation circuit wherein the processing is implemented by a digital type quadrature modulator 56. There, the frequency converter 7 is similar to the frequency converter 7 or frequency converter 79 shown in FIG. 1 or FIG. 4. Moreover, circuit components not otherwise specified are similar to those shown in FIG. 3 or FIG. 4.

[0084] In this embodiment, the modulation processing is implemented by a digital quadrature modulator (DSP: Digital Signal Processor) 56. Frequency of I' and Q' quadrature phase components in a base band digital modulating signal are digitally converted by an IF local signal. Thereafter, the IF signal converted in a method of quadrature modulation by the DSP 56 is converted into an analog signal by the D/A converter 3, and then input into frequency converter 7. Here, the frequency of the modulation phase signal further converted into that of a RF band is power amplified by the variable gain device 9, and synthesized with the modulation amplitude signal and then output as a modulated wave.

[0085] In this embodiment, it is enough to prepare only one phase modulation system D/A converter, as a D/A conversion is implemented after frequency conversion into the IF signal. Moreover, as modulation processing is implemented before the D/A conversion, the modulation processing can be implemented with still higher accuracy.

[0086] The present invention is not limited to the aforementioned embodiment but also, it can be practiced in different variation without departing from its technical scope.

Industrial Applicability

[0087] As described hereinbefore, in the present invention, the phase component and amplitude signal are extracted from the modulating signal in the phase signal/amplitude signal generation unit 1, the frequency conversion is implemented by the phase modulation in the phase component, and then power of the radio frequency signal is controlled by the amplitude signal in the amplifier. Therefore, modulated signal with little out of band noise 1 can be obtained, even if the modulating signal contains amplitude variation.

Claims

1. A modulation circuit for obtaining a modulated signal, by modulating a carrier signal using a modulating signal, comprising:

5 extracting means for extracting a phase signal and an amplitude signal from the modulating signal;
 analog converting means for converting the phase signal output from the extracting means into an analog signal and for outputting the analog signal;
 first frequency-signal generating means for generating a first oscillation frequency signal;
 10 quadrature modulating means for modulating, in use of quadrature modulation, the analog signal output from the converting means to an IF signal, based on the first oscillation frequency signal, and for outputting the IF signal;
 second frequency-signal generating means for generating a second oscillation frequency signal,
 frequency converting means for converting the frequency of the IF signal output from the quadrature modulating means and converting the IF signal into a RF signal, based on the second oscillation frequency signal,
 15 and for outputting the RF signal;
 delaying means for delaying the amplitude signal output from the extracting means for a time, and for outputting the amplitude signal; and
 outputting means for varying the amplitude of the RF signal and amplifying the varied RF signal in accordance with the delayed amplitude signal output from the delaying means, and for outputting the amplified RF signal.

2. The modulation circuit according to claim 1, further comprising power amplifying means for calculating a mean value of power values each of which corresponds to an output signal output from the modulation circuit and amplifying the amplified RF signal output from the outputting means based on the mean value.

3. The modulation circuit according to claim 1, wherein the delaying means comprises:

delay-time setting means for setting the time to delay the amplitude signal output from the extracting means;
 and
 30 a delay circuit for delaying the amplitude signal output from the extracting means in accordance with the time set by the delay-time setting means.

4. The modulation circuit according to claim 3, wherein the delay-time setting means includes a delay-time setting circuit for setting the time to delay the amplitude signal output from the extracting means based on at least one of signal format of the modulating signal, the frequency band of the modulating signal, and the ambient temperature.

5. The modulation circuit according to claim 1, further comprising correcting means for correcting the delayed amplitude signal output from the delaying means to correct the linearity of controlling gain variation in the outputting means using an equation or a conversion table.

6. A modulation circuit for obtaining a modulated signal, by modulating a carrier signal using a modulating signal, comprising:

45 extracting means for extracting a phase signal and an amplitude signal from the modulating signal;
 quadrature modulating means for digitally modulating, in use of quadrature modulation, the phase signal output from the extracting means to an IF signal, and for outputting the IF signal;
 analog converting means for converting the IF signal output from the quadrature modulating means into an analog IF signal, and for outputting the analog signal;
 frequency converting means for converting the frequency of the analog IF signal output from the analog converting means and converting the analog IF signal into a RF signal, and for outputting the RF signal;
 50 delaying means for delaying the amplitude signal output from the extracting means for a time, and for outputting the amplitude signal; and
 outputting means for varying the amplitude of the RF signal and amplifying the varied RF signal output from the frequency converting means in accordance with the delayed amplitude signal output from the delaying means, and for outputting the amplified RF signal.

7. The modulation circuit according to claim 1, wherein the frequency converting means includes a phase-synchronizing modulation loop filter for limiting the frequency band of the IF signal by a first filter, for driving the frequency

of the IF signal by a first counting-down circuit, for multiplying the second local oscillation frequency signal and the RF signal by a multiplier, for limiting the frequency band of an output signal from the multiplier by a second filter, for dividing the frequency of the output signal by a second counting-down circuit, for detecting the phase difference between output signals from the first and second counting-down circuits by a phase difference detector, for smoothing a signal corresponding to the detected phase difference by a third filter, and for outputting the RF signal.

8. The modulation circuit according to claim 1, wherein the frequency converting means includes a frequency converter for limiting the frequency band of the IF signal by a first filter, for multiplying the output signal from the first filter and the second local oscillation frequency signal by a multiplier, for limiting the frequency band of an output signal output from the multiplier by a second filter, and for outputting the RF signal.

9. A cellular phone comprising the modulation circuit according to claim 1.

10. A method for obtaining a modulated signal, by modulating a carrier signal using a modulating signal, comprising:

an extracting step for extracting a phase signal and an amplitude signal from the modulating signal;
an analog converting step for converting the phase signal output from the extracting step into an analog signal and for outputting the analog signal;
a first frequency-signal generating step for generating a first oscillation frequency signal;
a quadrature modulating step for modulating, in use of quadrature modulation, the analog signal output from the analog converting means to an IF signal, based on the first frequency signal, and for outputting the IF signal;
a second frequency-signal generating step for generating a second oscillation frequency signal;
a frequency converting step for converting the frequency of the IF signal output in the quadrature modulating step, for converting the IF signal into a RF signal, based on the second oscillation frequency signal, and for outputting the RF signal;
a delaying step for delaying the amplitude signal output in the extracting step for a time, and for outputting the amplitude signal; and
an amplifying step for varying the amplitude of the RF signal output in the frequency converting step and amplifying the varied RF signal in accordance with the delayed amplitude signal output in the delaying step, and outputting the amplified RF signal.

11. The method according to claim 10, further comprising a power amplifying step for calculating a mean value of power values each of which corresponds to an output signal due to the method, for amplifying the amplified RF signal output in the amplifying step based on the mean value, and for outputting the output signal.

12. The method according to claim 10, wherein the delaying step comprises:

a delay-time setting step for setting the time to delay the amplitude signal output from the extracting step; and
a delaying step for delaying the amplitude signal output in the extracting step in accordance with the time set by the delay-time setting step.

13. The method according to claim 12, wherein the delay-time setting step includes a delay-time setting step for setting the time to delay the amplitude signal output in the extracting step based on at least one of signal format of the modulating signal, the frequency band of the modulating signal, and the ambient temperature.

14. The method according to claim 10, further comprising a correcting step for correcting the delayed amplitude signal output in the delaying step to correct the linearity of controlling gain variation in the outputting step using an equation or a conversion table.

15. A modulation circuit for obtaining a modulated signal, by modulating a carrier signal using a modulating signal, comprising:

an extracting step for extracting a phase signal and an amplitude signal from the modulating signal;
a quadrature modulating step for digitally modulating, in use of quadrature modulation, the phase signal output in the extracting means to an IF signal and for outputting the IF signal;
an analog converting step for converting the IF signal output in the quadrature modulating means into an analog IF signal and for outputting the analog IF signal;

a frequency converting step for converting the frequency of the analog IF signal output in the analog converting means and converting the analog IF signal into a RF signal and for outputting the RF signal;
a delaying step for delaying the amplitude signal output in the extracting means for a time and for outputting the amplitude signal; and
5 an amplifying step for varying the amplitude of the RF signal output in the frequency converting means and amplifying the varied RF signal in accordance with the delayed amplitude signal output in the delaying means, and outputting the amplified RF signal.

16. The method according to claim 10, wherein the frequency converting step includes a phase-synchronizing modulation loop step for limiting the frequency band of the IF signal by a first filter, for dividing the frequency of the IF signal by a first counting-down circuit, for multiplying the second local oscillation frequency signal and the RF signal by a multiplier, for limiting the frequency band of an output signal output from the multiplier by a second filter, for
10 dividing the frequency of the output signal by a second counting-down circuit, for detecting the phase difference between output signals from the first and second counting-down circuits by a phase difference detector, for smoothing a signal corresponding to the detected phase difference by a third filter, for outputting the RF signal.

17. The method according to claim 10, wherein the frequency converting step includes a frequency band limiting step for limiting the frequency band of the IF signal output in the quadrature modulating step by a first filter, for multiplying the output signal from the first filter and the second local oscillation frequency signal by a multiplier, for limiting the
20 frequency band of an output signal output from the multiplier, and for outputting the RF signal.

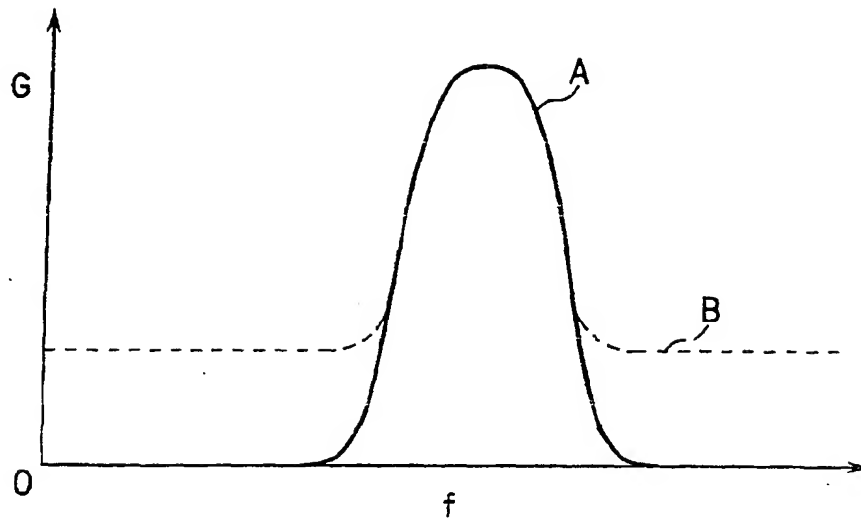


FIG. 1

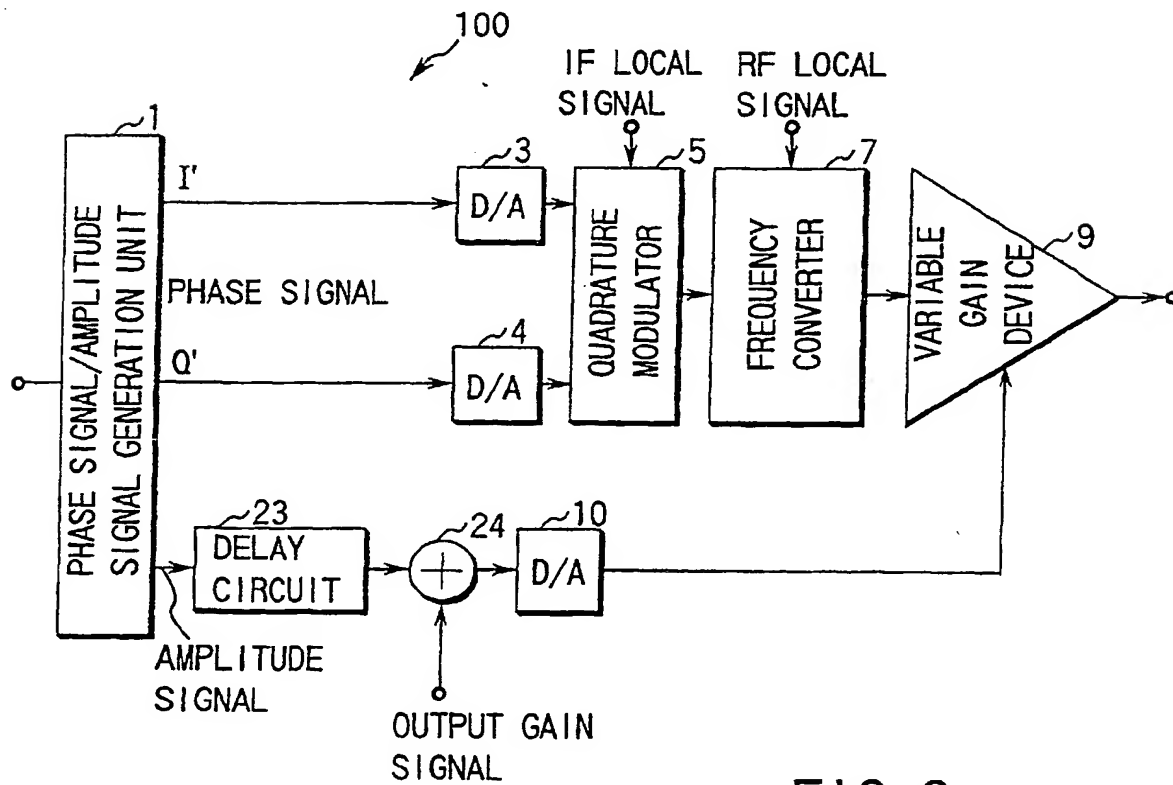


FIG. 3

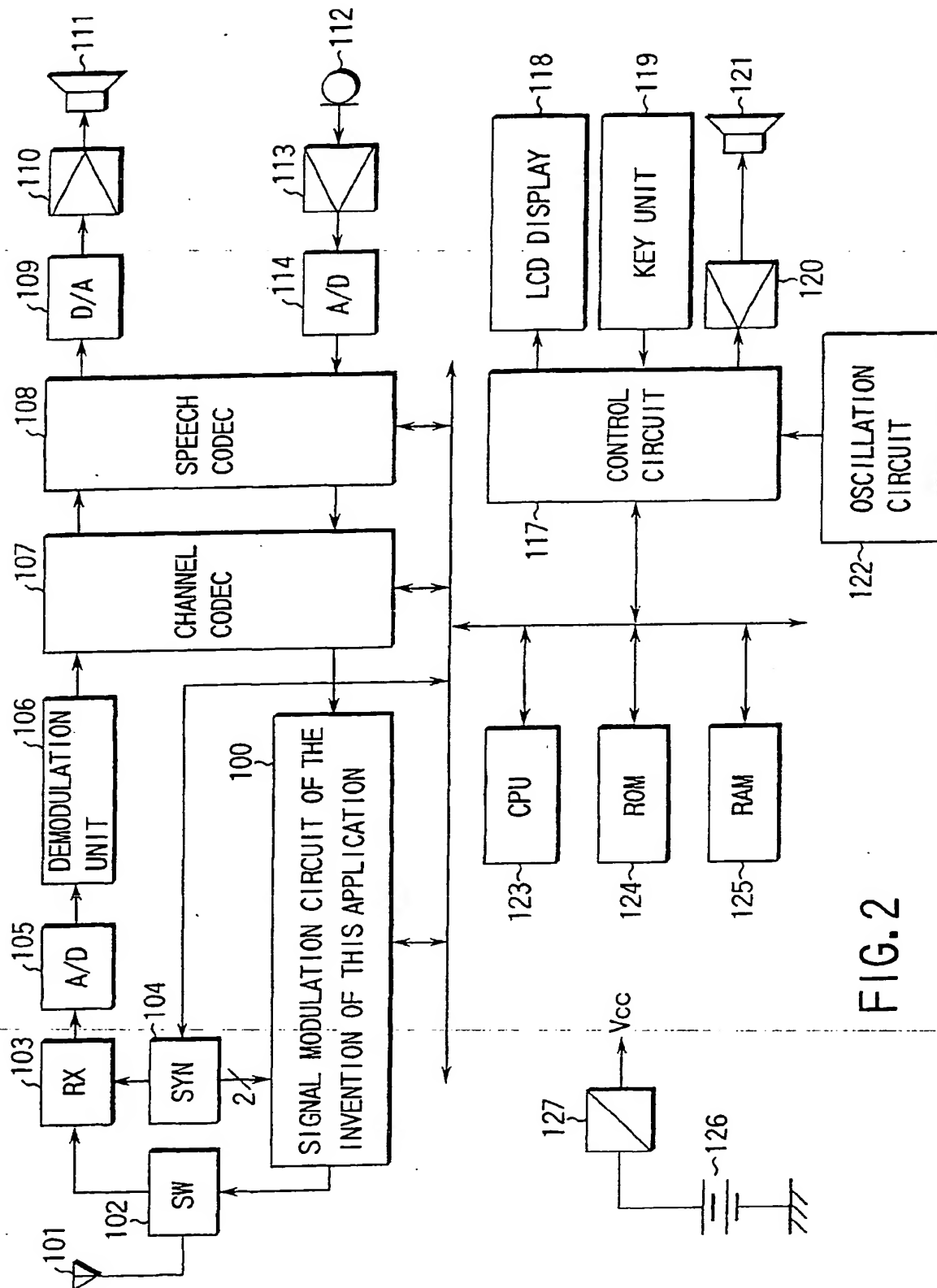


FIG. 2

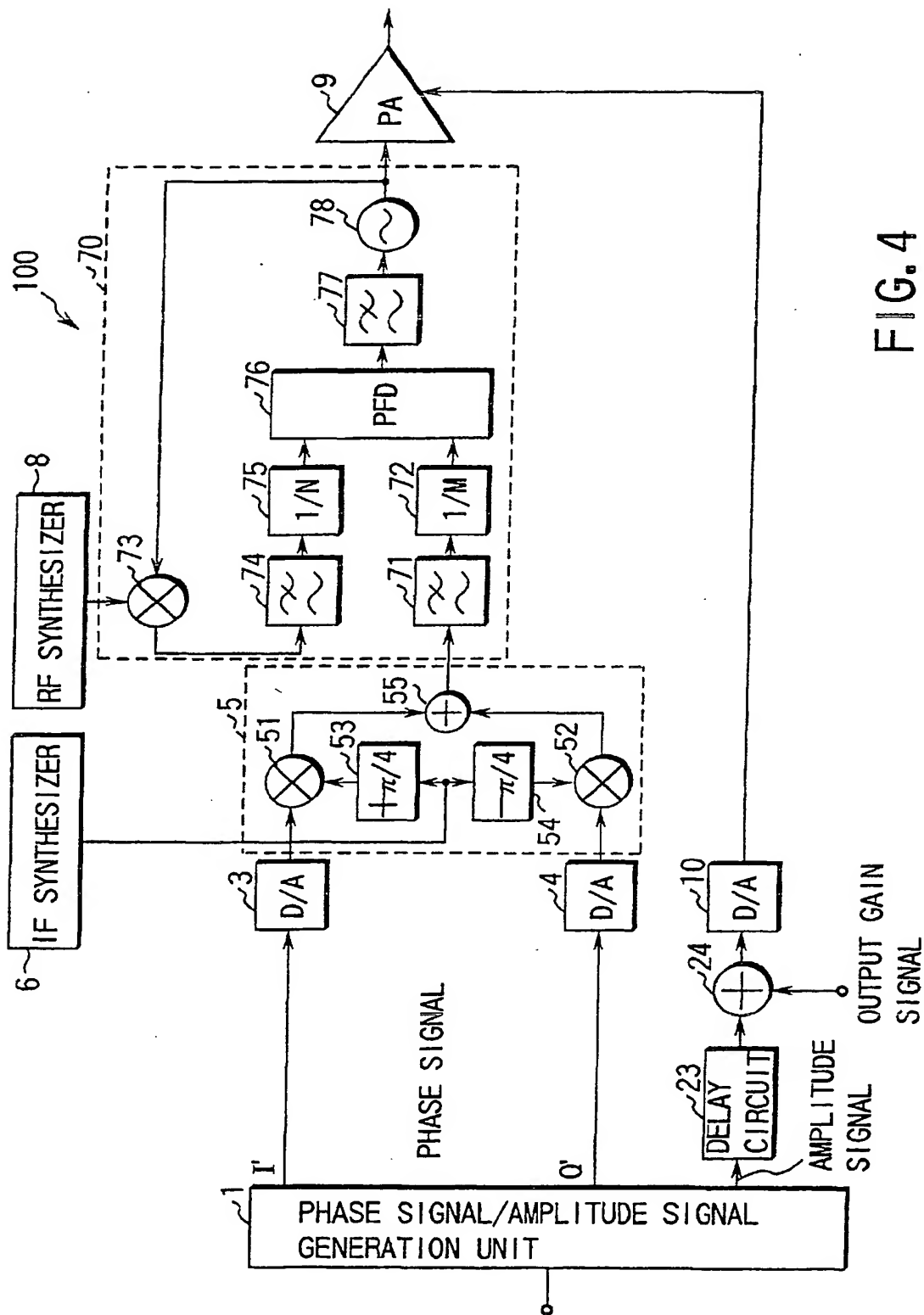


FIG. 4

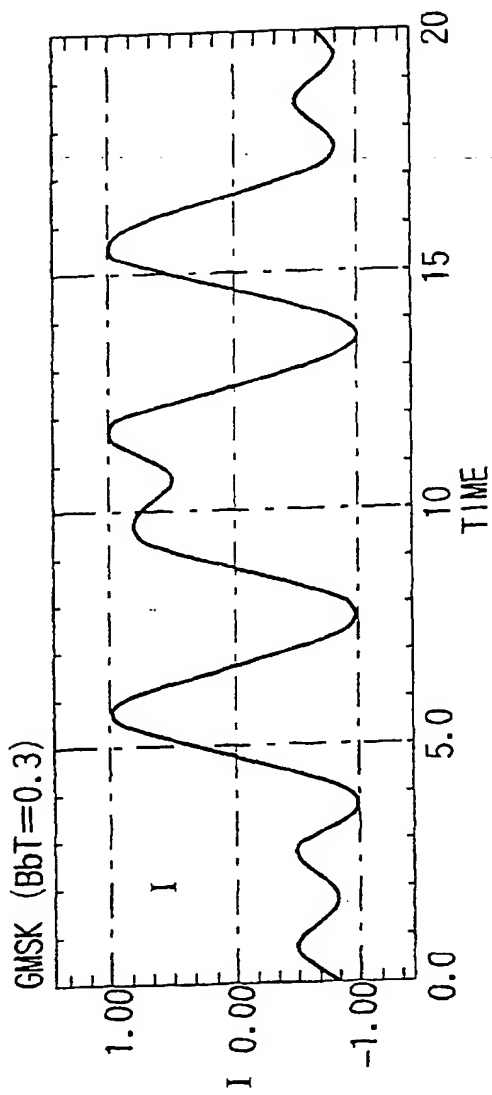


FIG. 5A

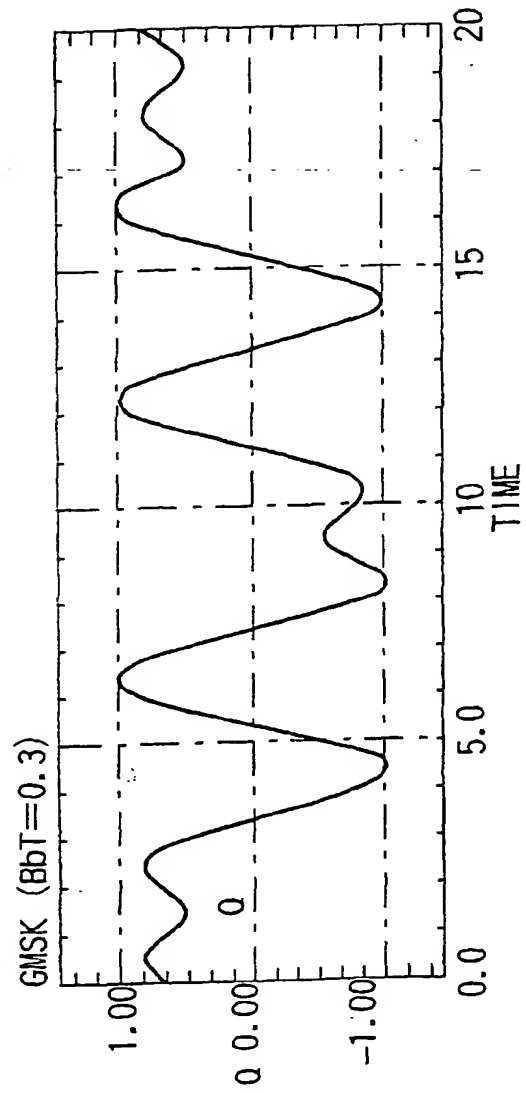


FIG. 5B

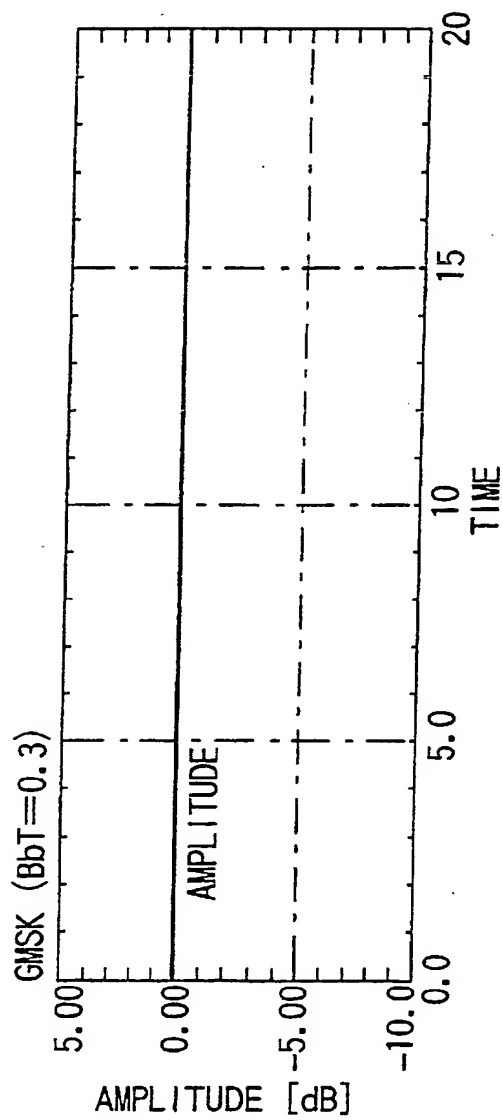


FIG. 6A

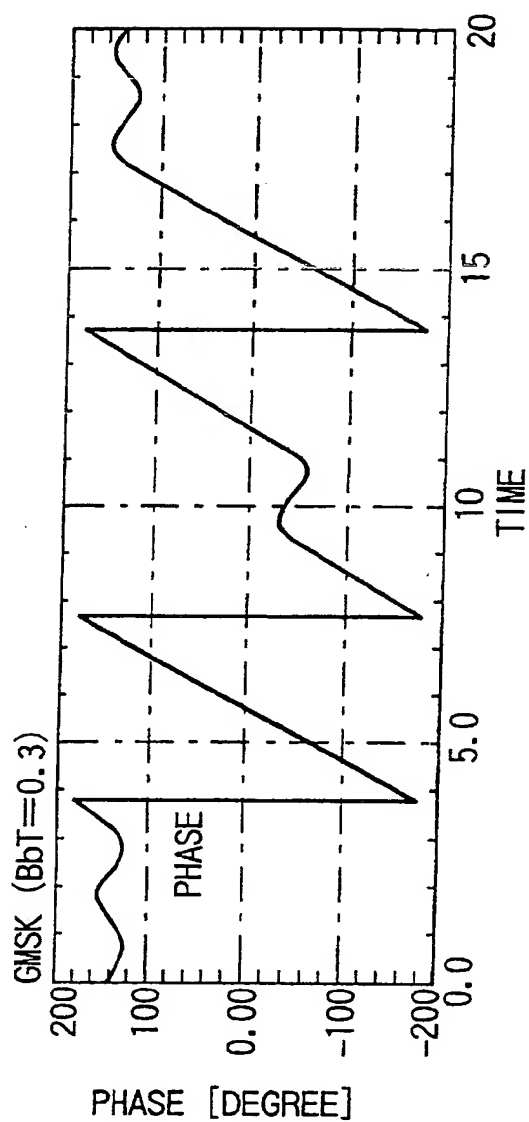


FIG. 6B

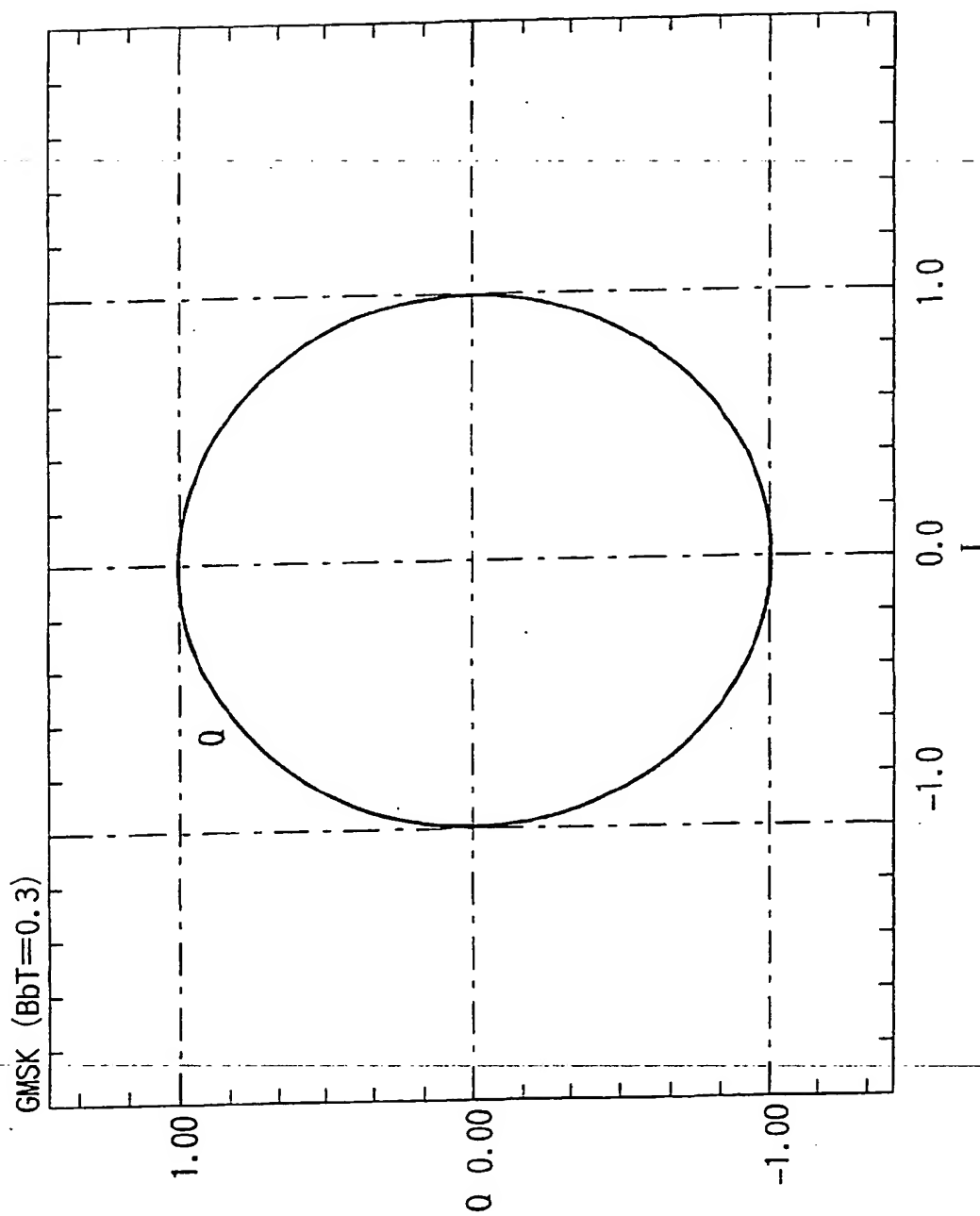


FIG. 7

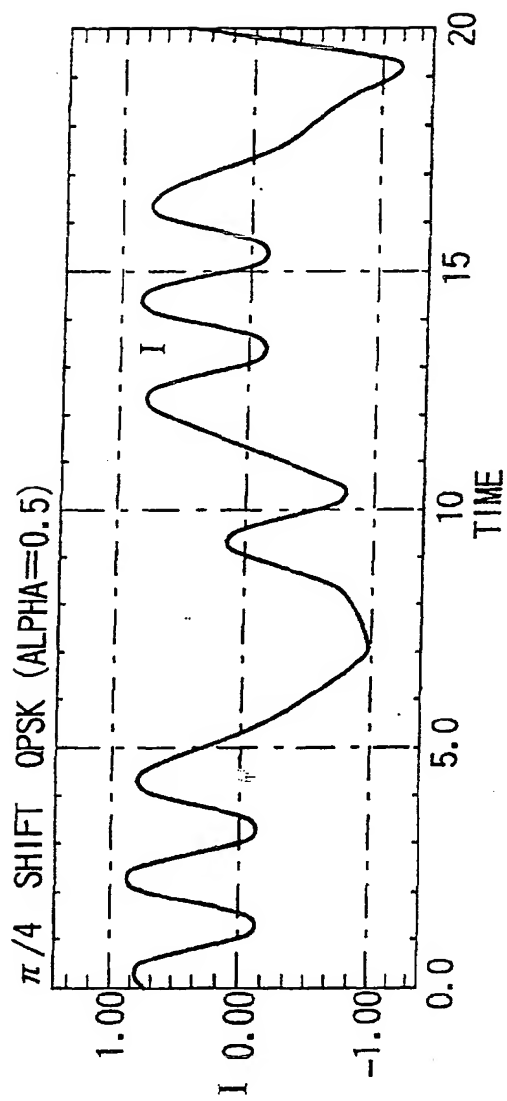


FIG. 8A

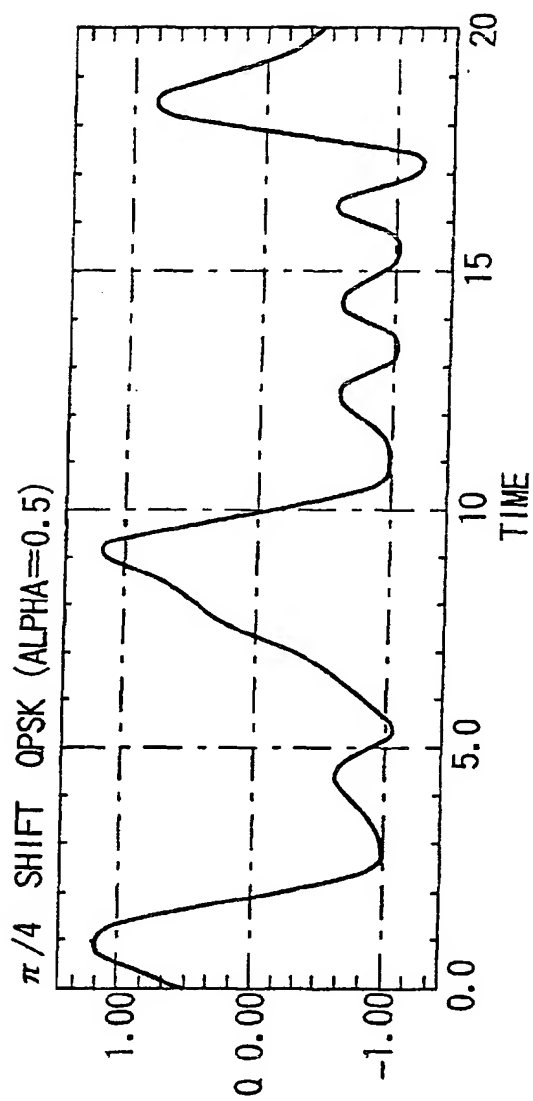


FIG. 8B

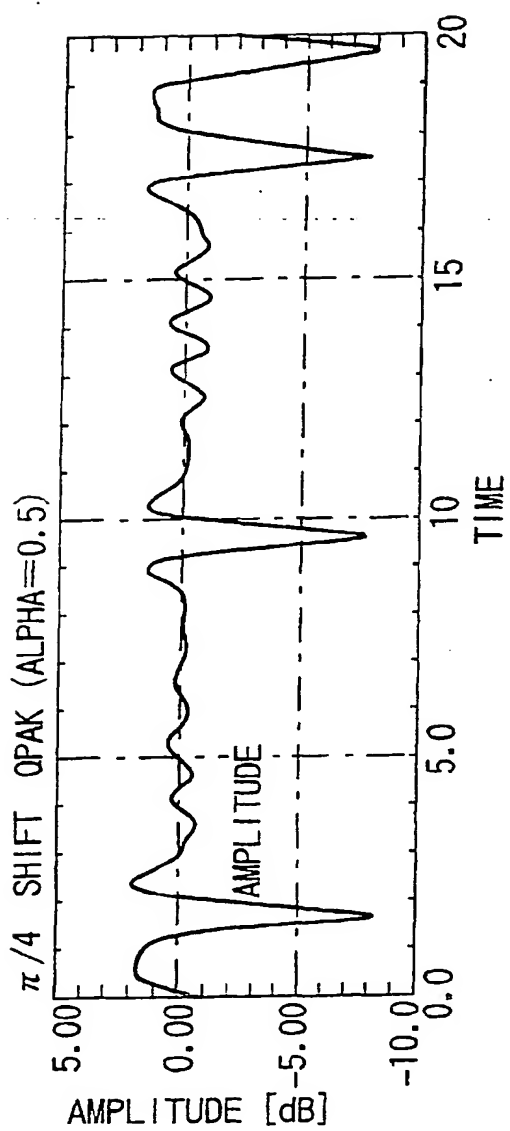


FIG. 9A

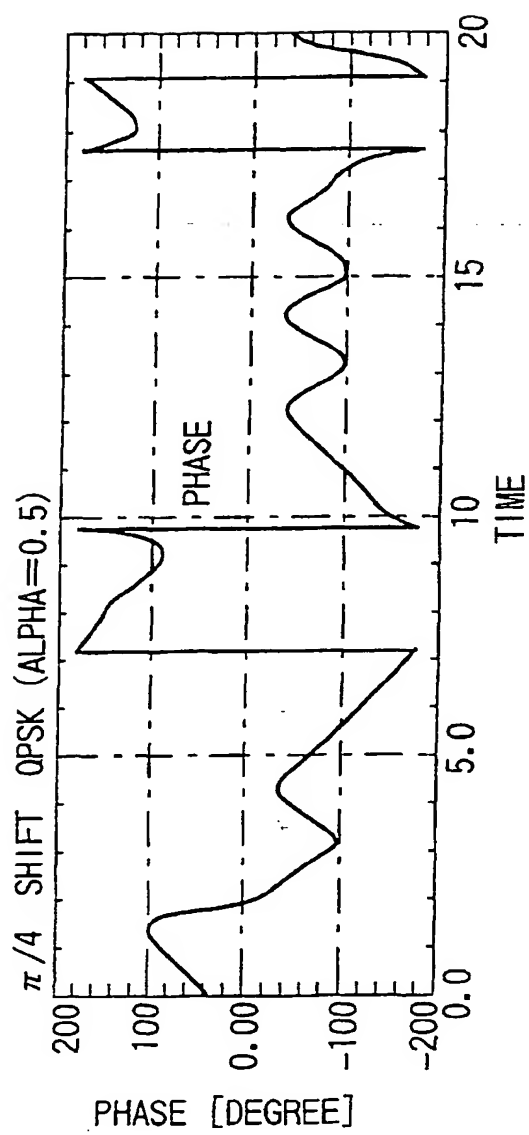


FIG. 9B

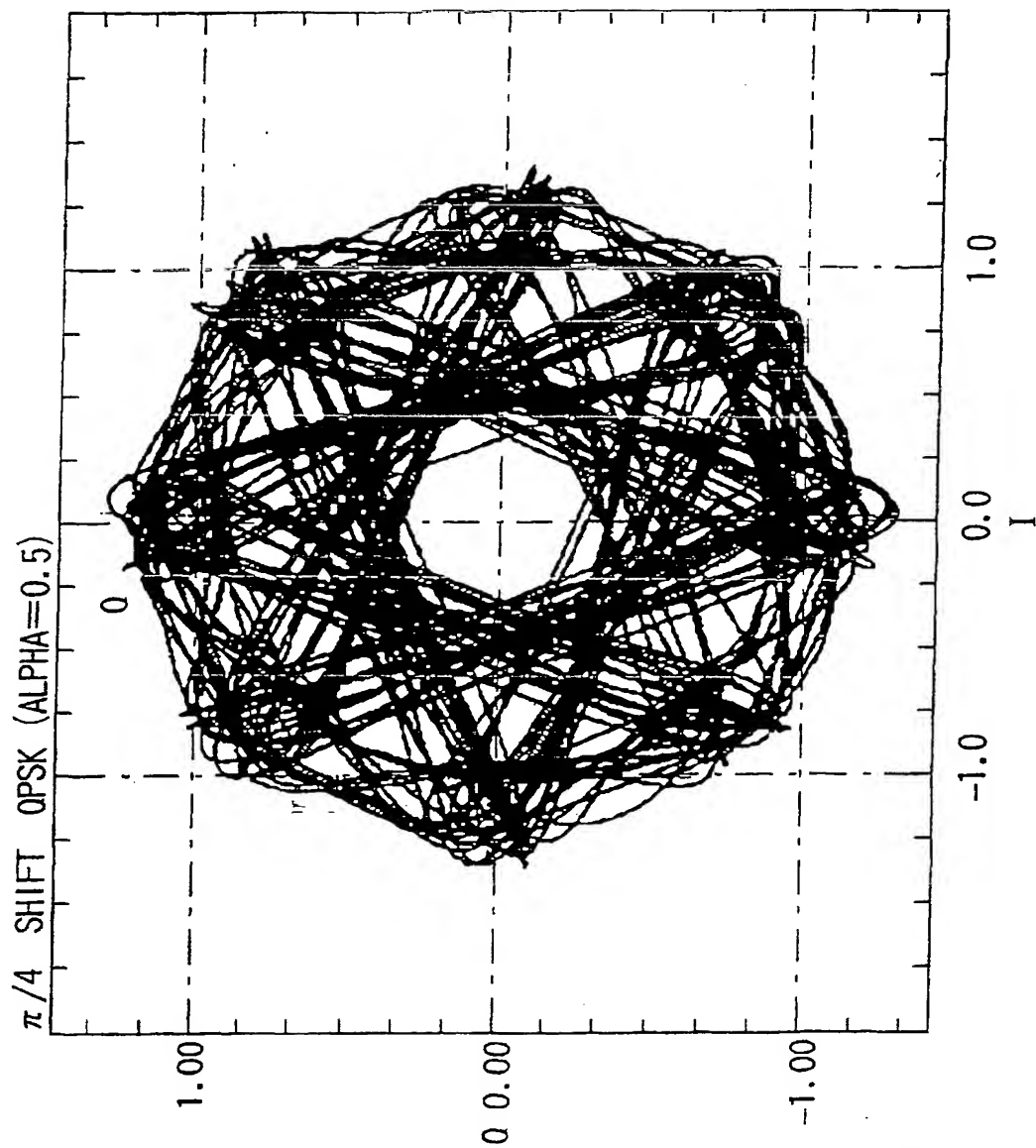


FIG.10

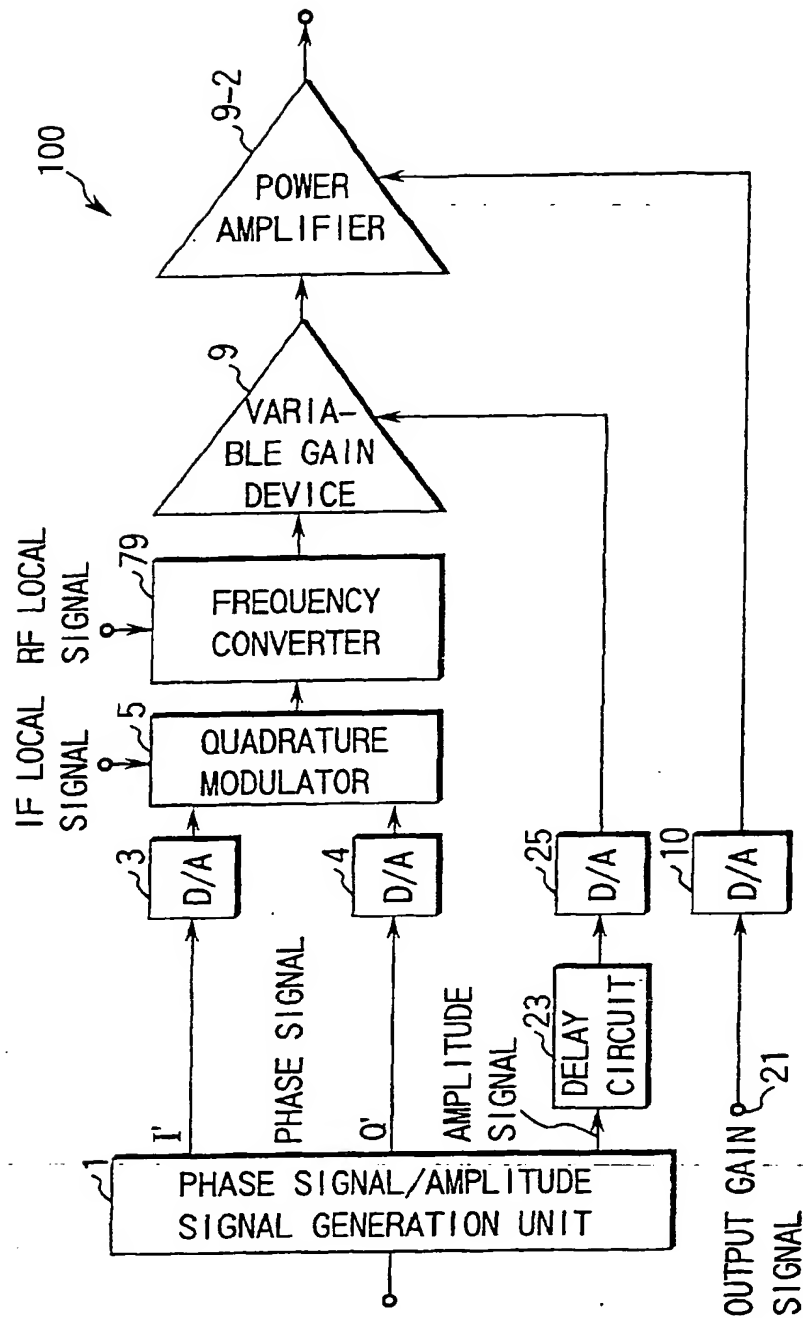


FIG. 11

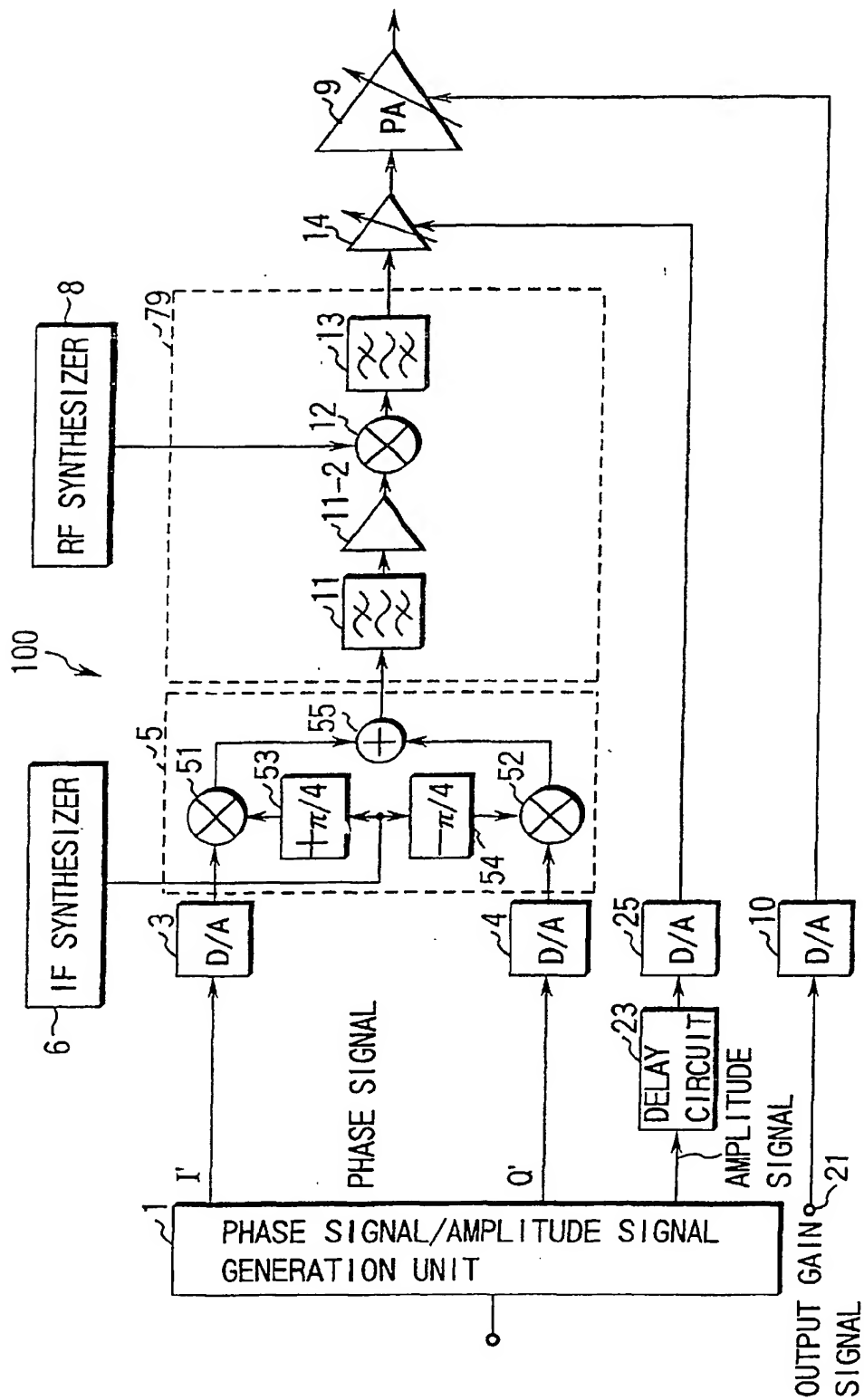


FIG. 12

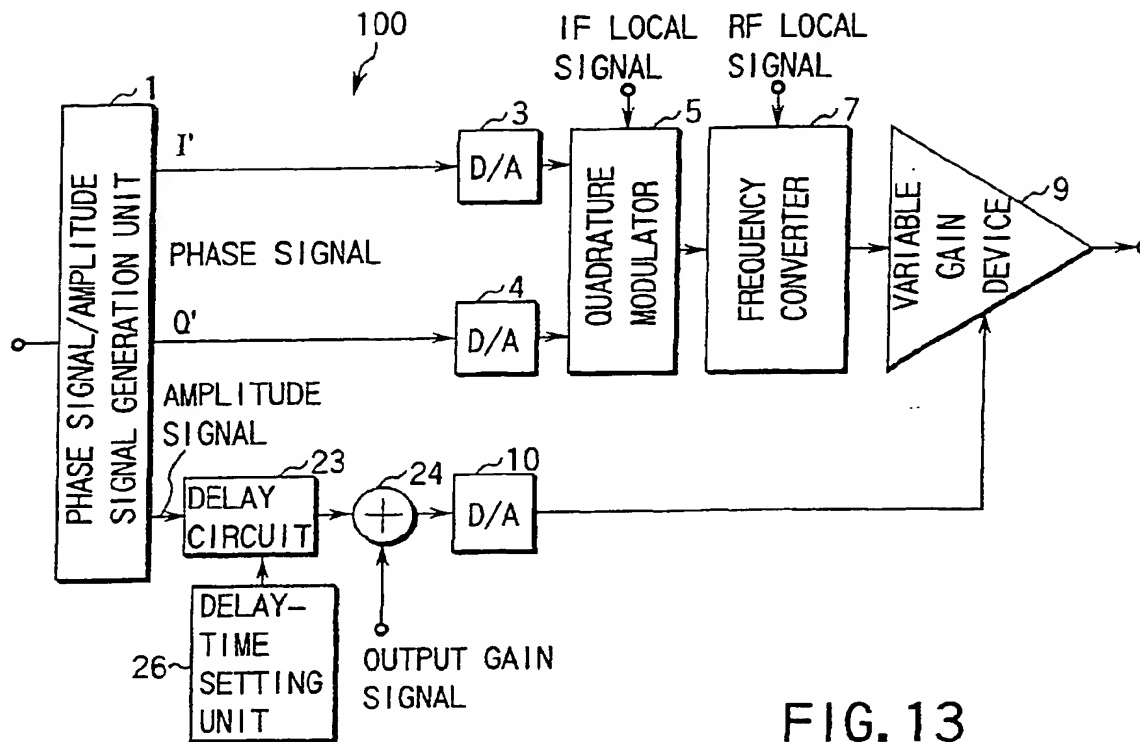


FIG. 13

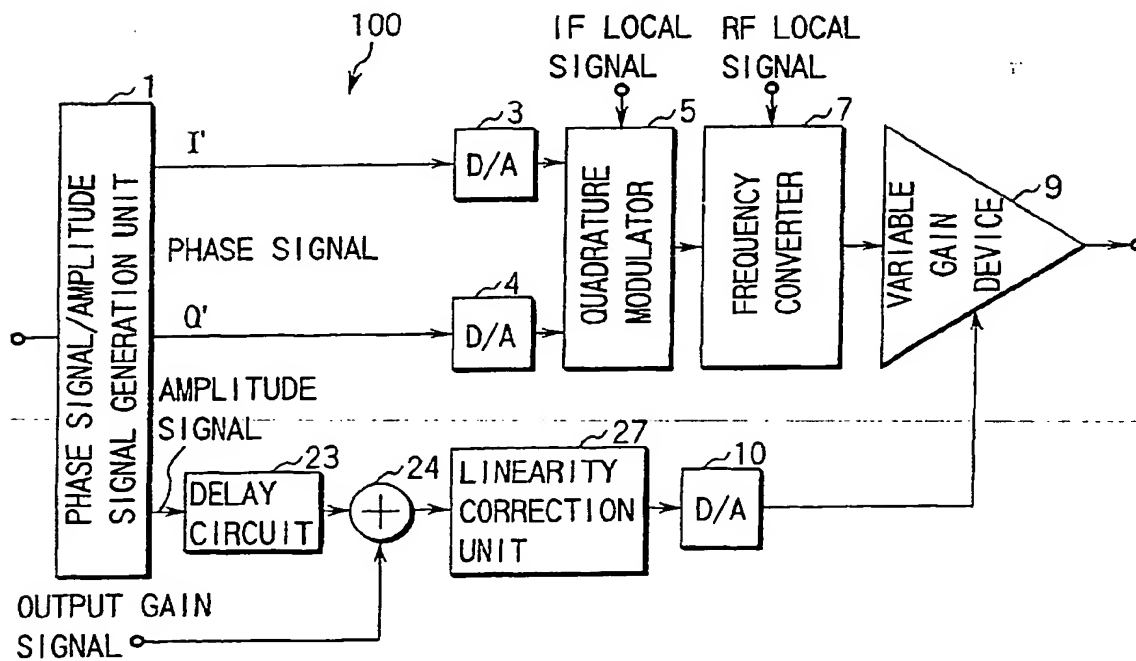


FIG. 14

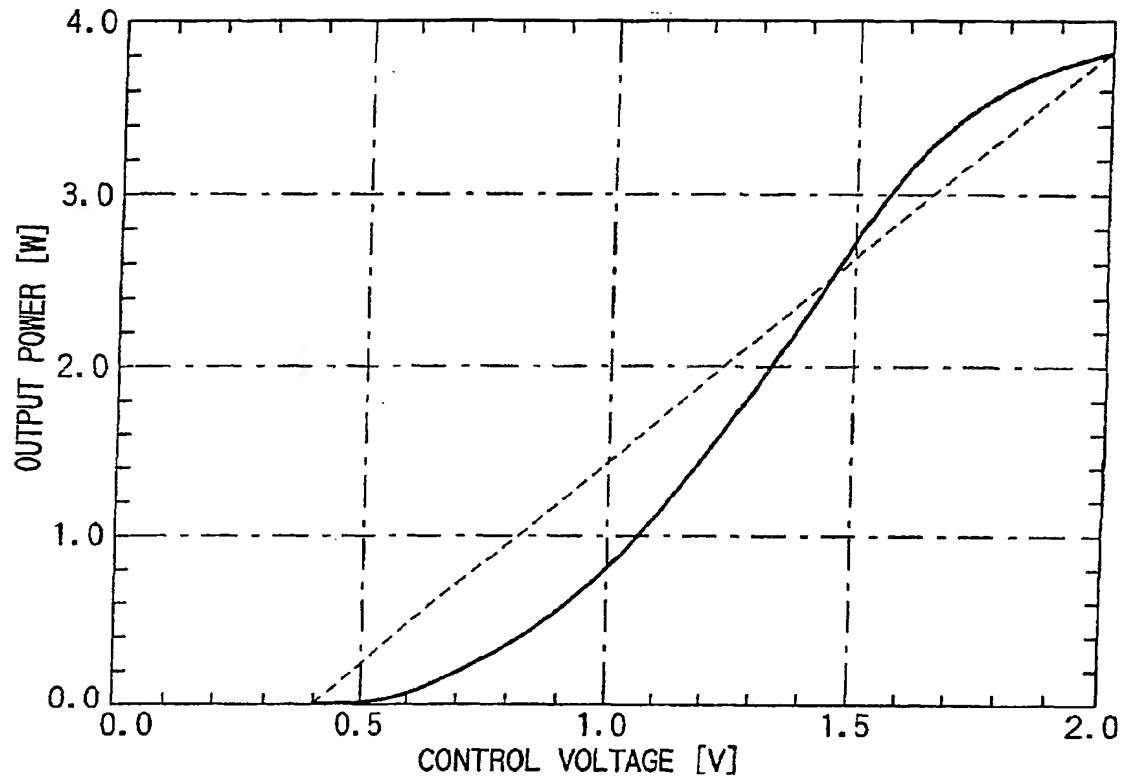


FIG. 15

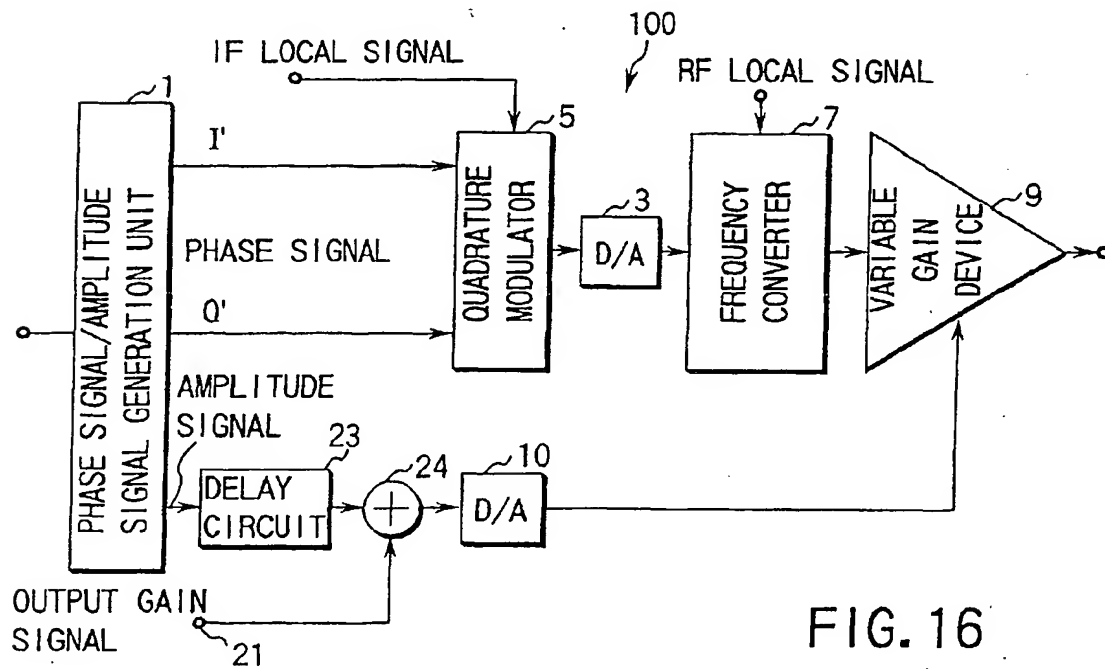


FIG. 16

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP00/02124

A. CLASSIFICATION OF SUBJECT MATTER Int.Cl. ⁷ H04L27/20		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) Int.Cl. ⁷ H04L27/20, 27/36		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1926-1996 Toroku Jitsuyo Shinan Koho 1994-2000 Kokai Jitsuyo Shinan Koho 1971-2000 Jitsuyo Shinan Toroku Koho 1996-2000		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 3-171953, A (Mitsubishi Electric Corp.), 25 July, 1991 (25.07.91), page 3, upper left column to page 4, upper left column; Figs. 1, 4	1-3, 5, 6, 8-12, 14, 15, 17 4, 7, 13, 16
A		
Y	JP, 3-265333, A (Fijitsu Limited), 26 November, 1991 (26.11.91), page 4, lower left column, line 14 to lower right column, line 10; Fig. 1 (Family: none)	1-3, 5, 6, 8-12, 14, 15, 17 4, 7, 13, 16
A		
Y	JP, 9-326835, A (Hitachi Denshi Ltd.), 16 December, 1997 (16.12.97), Fig. 2 (Family: none)	1-3, 5, 6, 8-12, 14, 15, 17 4, 7, 13, 16
A		
Y	EP, 431201, A1 (Nippon Telegraph and Telephone Corp.), 28 June, 1990 (28.06.90), Fig. 6 & JP, 3-104422, A	1-3, 5, 6, 8-12, 14, 15, 17 4, 7, 13, 16
A		
E, X	JP, 2000-138723, A (Nokia Mobile Phones Limited), 16 May, 2000 (16.05.00), (Family: none)	1, 10
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family	
Date of the actual completion of the international search 27 June, 2000 (27.06.00)		Date of mailing of the international search report 11 July, 2000 (11.07.00)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP00/02124

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO, 94/24759, A1 (Acrodyne Industries, Inc.), 27 October, 1994 (27.10.94), & JP, 8-509333, A	1-17
A	WO, 95/16304, A1 (National Semiconductor Corporation), 15 June, 1995 (15.06.95), & US, 5511236, A & JP, 9-505695, A	7,16
A	JP, 5-347642, A (Robert Bosch GmbH), 27 December, 1993 (27.12.93), (Family: none)	7,16

Form PCT/ISA/210 (continuation of second sheet) (July 1992)